BMP #40 - Sand Filter

Targeted Pollutants

85% Sediment

55% Phosphorus

Trace metals

Bacteria

Petroleum hydrocarbons

Physical Limits

Drainage area 5 ac inlets, 50 ac basins

Max slope 10%

Min bedrock depth 3 feet

Min water table 3 feet

SCS soil type N/A

Freeze/Thaw fair

Drainage/Flood control yes

DESCRIPTION

Sand filters are devices which filter stormwater runoff through a sand layer into an underdrain system which conveys the treated runoff to a detention facility or to the ultimate point of discharge. The sand bed filtration system consists of an inlet structure, sedimentation chamber, sand bed, underdrain piping and liner to protect against infiltration.

There are several variations of sand filters, including the sand filtration trench (also referred to as a sand filter inlet) and the sand filtration basin, both discussed in this fact sheet.

Application and Limitations

In general, sand filters take up little space and can be used on highly developed sites and sites with steep slopes. They can be added to retrofit existing sites. **This BMP is not recommended where high sediment loads are expected, unless pretreatment (e.g., sedimentation) is provided, since sediment clogs sand filters;** or where the runoff is likely to contain high concentrations of toxic pollutants (e.g., heavy industrial sites).

Sand filtration trenches are generally used for smaller drainage areas than sand filtration basins. A typical use of a trench is along the perimeter of a parking lot. Trenches have experienced fewer problems with clogging than basins, perhaps because their use in the field has been limited more to high impervious cover sites which may generate less suspended solids.

Sand filters rely on physical straining, pollutant settling and pollutant adsorption to remove pollutants. They are very effective at removing total suspended solids with moderate removal (55%) for total phosphorus. Depending on agency approval, sand filtration may substitute for API and CPS-type oil/water separators (see BMP #52) to remove oil from runoff.

To improve the effectiveness of sand filtration basins and to protect the media from clogging, basins should be located off-line from the primary conveyance/detention system and must be preceded by a pretreatment BMP. Disturbed areas that are sediment sources in the contributing drainage area should be identified and stabilized to the maximum extent practicable. Smaller filters, such as a sand filtrations trench in a parking lot, can be installed on-line.

Because of the potential for clogging, sand filtration BMPs should never be used as sediment basins during construction.

In area with high water table conditions and the possibility of groundwater contamination liners are recommended for trenches and basins.

Design Parameters

Off-Line Isolation/Diversion Structure

By locating sand filtration systems off-line from the primary conveyance/detention system, the long-term effectiveness of the treatment system can be maintained. Off-line systems are designed to capture and treat the locally-specified design storm (see Appendix D); this is typically achieved by using isolation/diversion baffles and weirs. A typical approach for achieving isolation of the water quality volume is to construct an isolation/diversion weir in the stormwater channel such that the height of the weir equals the maximum height of water in the filtration basin during the water quality design storm. When additional runoff greater than the water quality storm enters the stormwater channel, it will spill over the isolation/diversion weir and mixing with the already-isolated water quality volume will be minimal.

Sizing Sand Filtration BMPs

The Darcy's Law method for sizing the BMP should be used:

$Q = (f)(i)(As)$

where

Q = flowrate at which runoff is filtrated

f = infiltration rate of sand

i = hydraulic gradient

As = surface area of the filtration bed

Conservative values of "f" should be used. For infiltration BMPs, a factor of safety of two should be applied to the infiltration rate determined from the textural analysis and, hereafter, the design infiltration rate will be labeled "fd" where fd = 0.5 * f. For sand infiltration BMPs, an "f" value of about 2 inches (50 mm) per hour is recommended for design purposes. This appears to be a low value but reflects actual rates achieved by operating sand infiltration systems treating urban runoff.

The hydraulic gradient is given by the equation:

i = h + L

L

where h is the height of the water column over the top of the sand bed and L is the thickness of the sand bed (typically 18 inches (450 mm)).

A conservative value for the filtration rate (f) should be used. Design filtration rates of about two inches/hour are used in Austin, Texas, which are much lower than published values for sand but reflect actual field permeability rates. The lower rates reflect the effects of suspended solids and sediment on the sand's permeability.

Drawdown Time (basins)

Sand filtration basins are to be designed to completely empty in 24 hours or less.

Inlet Structure

The inlet structure to the sand filter should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs or multiple orifice openings are recommended. Stone riprap or other dissipation devices should be installed to prevent gouging of the sand media and to promote uniform flow.

Sand Bed

A sand bed depth of 18 inches (450 mm) is recommended. This is the final bed depth; consolidation of the sand is likely during construction.

Two sand bed configurations can be selected from; one with a gravel layer and the other a trench design which utilizes drainage matting as a substitute for the gravel layer. The top surface layer should be level so that equal distribution of runoff will be achieved in the basin.

1. Sand Bed with Gravel Layer

The top layer is to be a minimum of 18 inches (450 mm) of 0.02-0.04 inch (0.51-1.02 mm) diameter sand (smaller sand size is acceptable). Under the sand should be a layer of .5 to 2 inch (12.7 to 50 mm) diameter gravel which provides a minimum of 2 inches (50 mm) of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. The sand and gravel must be separated by a layer of geotextile fabric meeting the specifications listed in BMP #13.

2. Sand Bed with Trench Design

This configuration can be used on flatter sites which may restrict the applicability of the previous design. The top layer should be 12 to 18 inches (300 to 450 mm) of 0.02-0.04 inch (0.51 to 1.02 mm) diameter sand (smaller sand size is acceptable). Laterals should be placed in trenches with a covering of .5 to 2 inch (12.7 to 50 mm) gravel and geotextile fabric. The lateral pipes should be underlain by a layer of drainage matting. The geotextile fabric is needed to prevent the filter media from infiltrating into the lateral piping. The drainage matting is needed to provide adequate hydraulic conductivity to the laterals.

Sand Filtration Liners

Liners for sand filters are recommended in areas with drinking water aquifers and should meet the specifications below.

- Impermeable liners may be either clay, concrete or geomembrane
- The clay liner should have a minimum thickness of 12 inches (300 mm).
- If a geomembrane liner is used instead of clay, it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane. Equivalent

methods for protection of the geomembrane liner may be considered by the local permitting authority.

- Concrete liners may also be used for sedimentation chambers and for sedimentation and filtration basins less than 1,000 square feet (100 m^2) in area. Concrete should be 5 inches (125 mm) thick Class A or better and should be reinforced by steel wire mesh. The steel wire mesh should be 6 gauge wire or larger and 6 inch x 6 inch (150 x 150 mm) mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton (2.5 metric ton) per square foot or less, the concrete should have a minimum 6 inch (150 mm) compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to one inch. Where visible, the concrete should be inspected annually and all cracks should be sealed.

Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be 4 inches (100 mm) or greater and perforations should be 3/8 inch (10 mm).. All piping is to be schedule 40 polyvinyl chloride or greater strength. A maximum spacing of 10 feet (3 meters) between laterals is recommended. Lesser spacings are acceptable. The maximum spacing between rows of perforations should not exceed 6 inches (150 mm).

The minimum grade of piping should be 1/8 inch per foot (one percent slope). Access for cleaning all underdrain piping is needed; this can be provided by installing cleanout ports which tee into the underdrain system and surface above the top of the sand filtration media.

Pretreatment for Sand Filters

It is recommended that a presettling basin (BMP #50) and/or vegetated swale (BMP #38) be used to pretreat runoff discharging to the sand filter.

If a presettling basin is used for pretreatment, careful attention must be given to designing the inlet and outlet structures. The presettling basin consists of an inlet structure, outlet structure and basin liner if permeable soils underlay the basin. The presettling basin design should maximize the distance between the location where the heavier sediment is deposited near the inlet to where the outlet structure is located. This will improve basin performance and reduce maintenance requirements.

Inlet Structure - The inlet structure design must be adequate for isolating the water quality volume from the larger design storms and to convey the peak flows for the larger design storms past the basin. The water quality volume should be discharged uniformly and at low velocity into the presettling basin in order to maintain near quiescent conditions which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin; thus a drop inlet structure is recommended in order to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary in order to reduce inlet velocities which exceed three 3 feet per second (1 m/second).

Outlet Structure - The outlet structure conveys the water quality volume from the presettling basin to the filtration basin. The outlet structure should be designed to provide for a residence time of 24 hours for the 6-month, 24-hour storm. The residence time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe (the discharges through the perforations should not be used for drawdown time design purposes).

A trash rack should be provided for the outlet. Openings in the rack should not exceed 1/2 the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations it is recommended that geotextile be wrapped over the pipe's bottom rows and that a cone of one to three inch diameter gravel be placed around the pipe. If a geotextile fabric wrap is not used then the gravel cone must not include any gravel small enough to enter the riser pipe perforations.

Basin Liner - The pretreatment BMP may need to have a basin liner to prevent runoff from being lost to soil infiltration prior to treatment by the filtration basin.

Observation Well

An observation well should be installed every 50 feet (15.25 meters) of BMP length. The observation well will serve two primary functions: it will indicate how quickly the trench dewaters following a storm and it will provide a method of observing how quickly the trench fills up with sediments.

The observation well should consist of perforated PVC pipe, 2 to 4 inches (50 to 100 mm) in diameter. It should be located in the center of the structure and be constructed flush with the ground elevation of the trench. The top of the well should be capped to discourage vandalism and tampering. More specific construction information can be obtained by contacting Idaho Department of Water Resources (IDWR) or DEQ.

Sand Filters for Oil Removal

If a sand filtration basin is used as a substitute for an API or CPS-type oil/water separator, then pretreatment may not be necessary if the contributing drainage area is small and completely impervious (the restrictions which apply to oil/water separators will also apply to sand filtration basins in this case - see BMP #52-Oil/Water Separation for further details.

Construction Guidelines

- The final sand bed depth must be 18 inches (450 mm); consolidation of sand will likely occur during installation and this must be taken into account. The sand should be periodically wetted, allowed to consolidate, and then extra sand added. Repeat this procedure until the bed depth has stabilized at 18 inches.

- Provisions must be made for access to the basin for maintenance purposes. A maintenance vehicle access ramp is necessary. The slope of the ramp should not exceed 4:1.

- The design should minimize susceptibility to vandalism by use of strong materials for exposed piping and accessories.

- Side slopes for earthen embankments should not exceed 3:1 to facilitate mowing.

- No runoff is to enter the sand filtration basin prior to completion of construction and site revegetation.

Maintenance

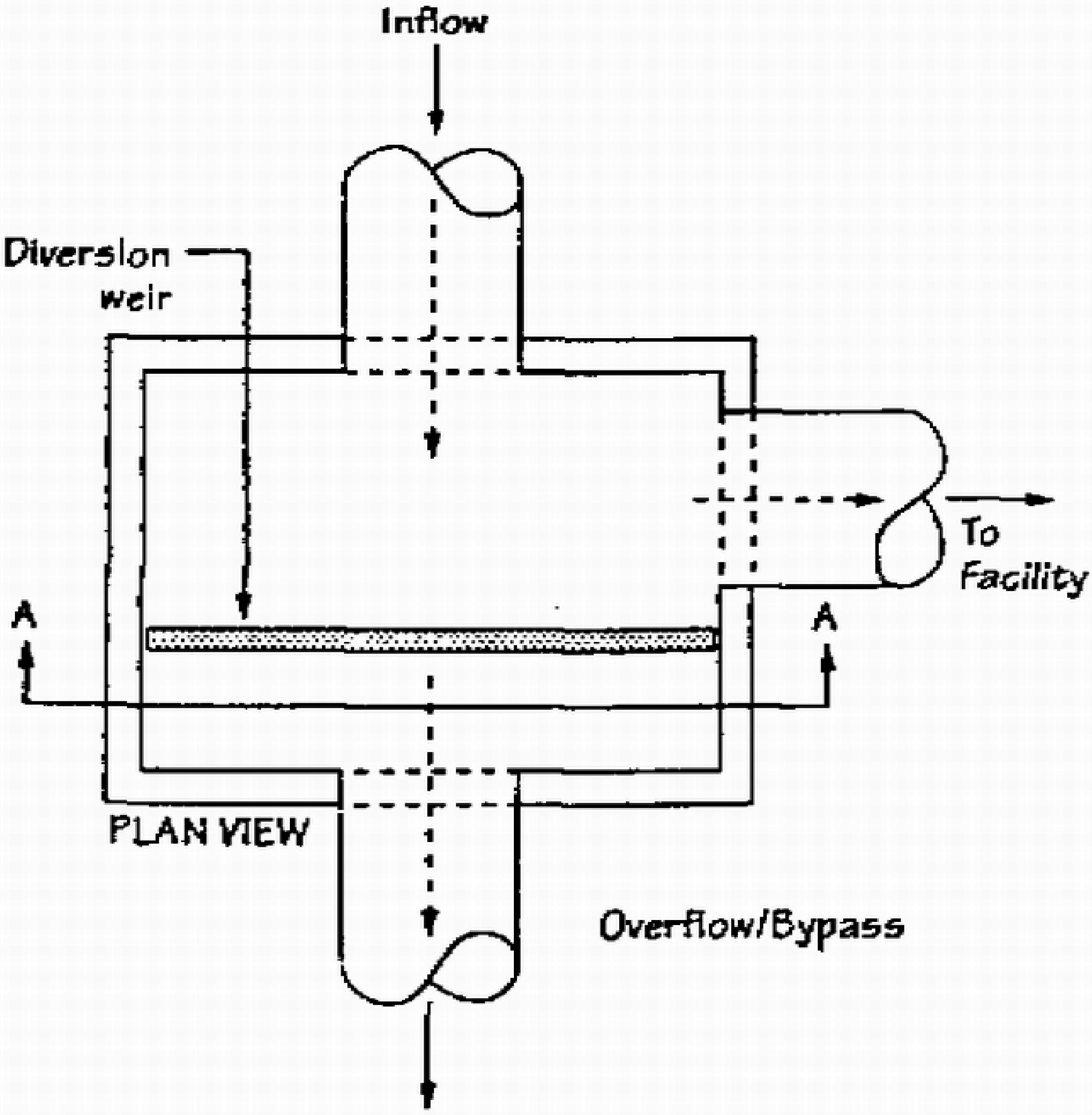
Follow the guidelines below for inspection and maintenance of sand filters.

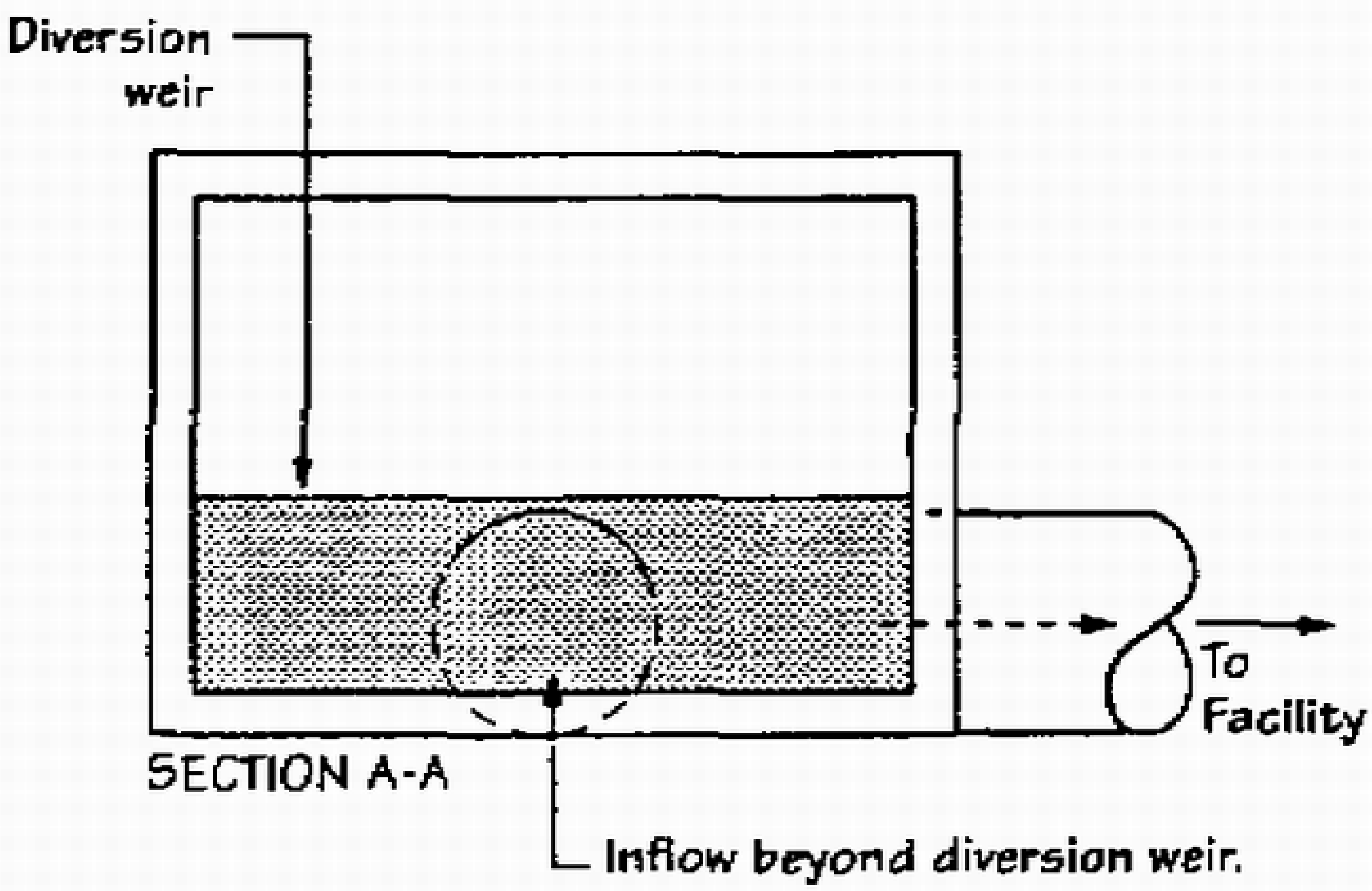
Inspection Schedule. Inspect the sand filters at least annually. Additionally, the observation well in a filtration trench should be monitored for water quality periodically. For the first year after completion of construction, the well should be monitored after every large storm (> 1 inch (25 mm) in 24 hours), and during the period from October 1 to March 31, inspections should be conducted monthly. From April 1 through September 30, the facility should be monitored on a quarterly basis. A log book should be maintained by the responsible person designated by the local government indicating the rate at which the facility dewaters after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis unless the performance data indicate that a more frequent schedule is required.

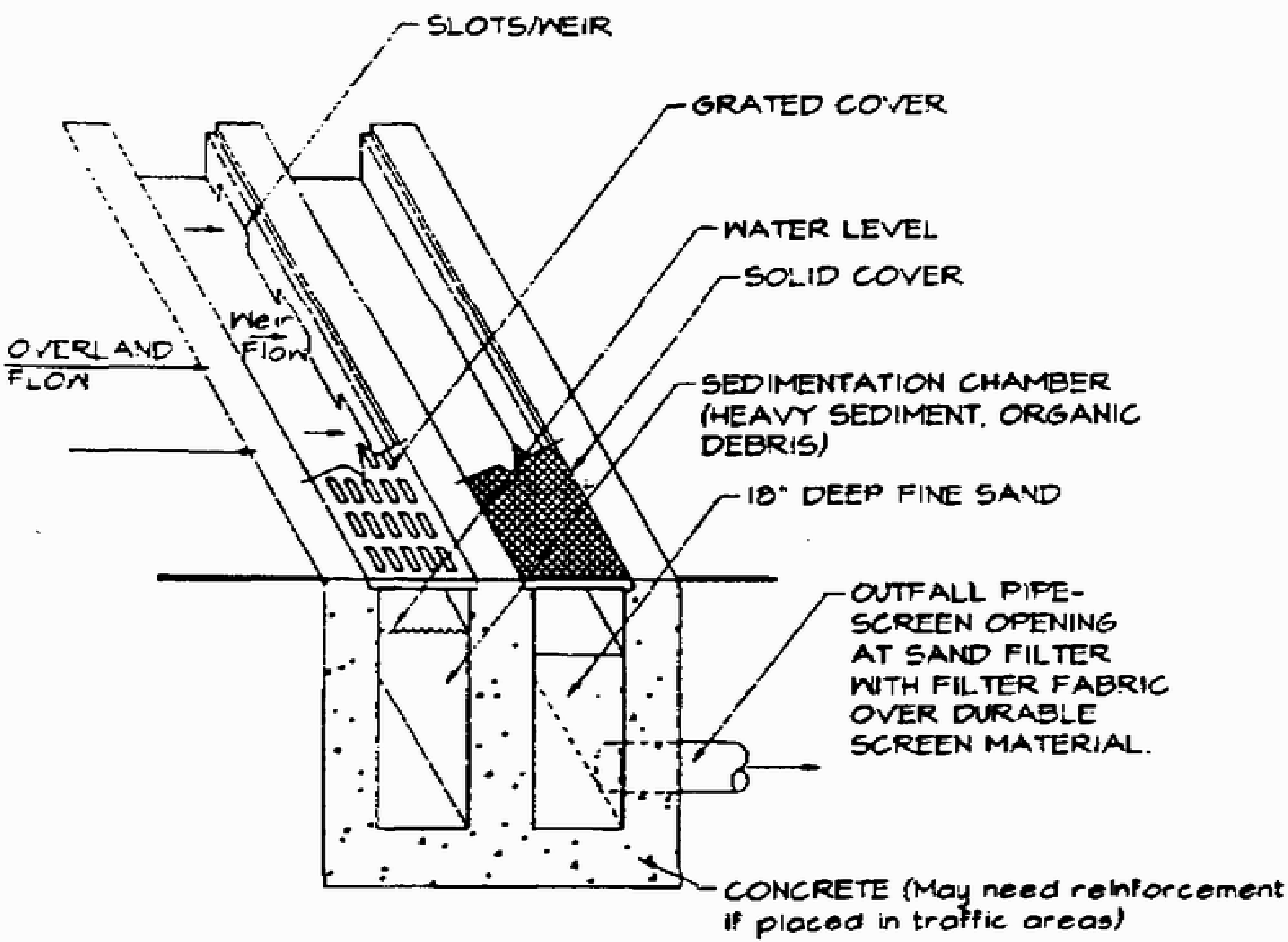
Sediment and Debris Removal. Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate should be required when the trench has a stone surface. Sediment deposits should not be allowed to build up to the point where they will reduce the rate of infiltration into the device. As a rule of thumb, remove silt when accumulation exceeds one-half inch (12.7 mm).

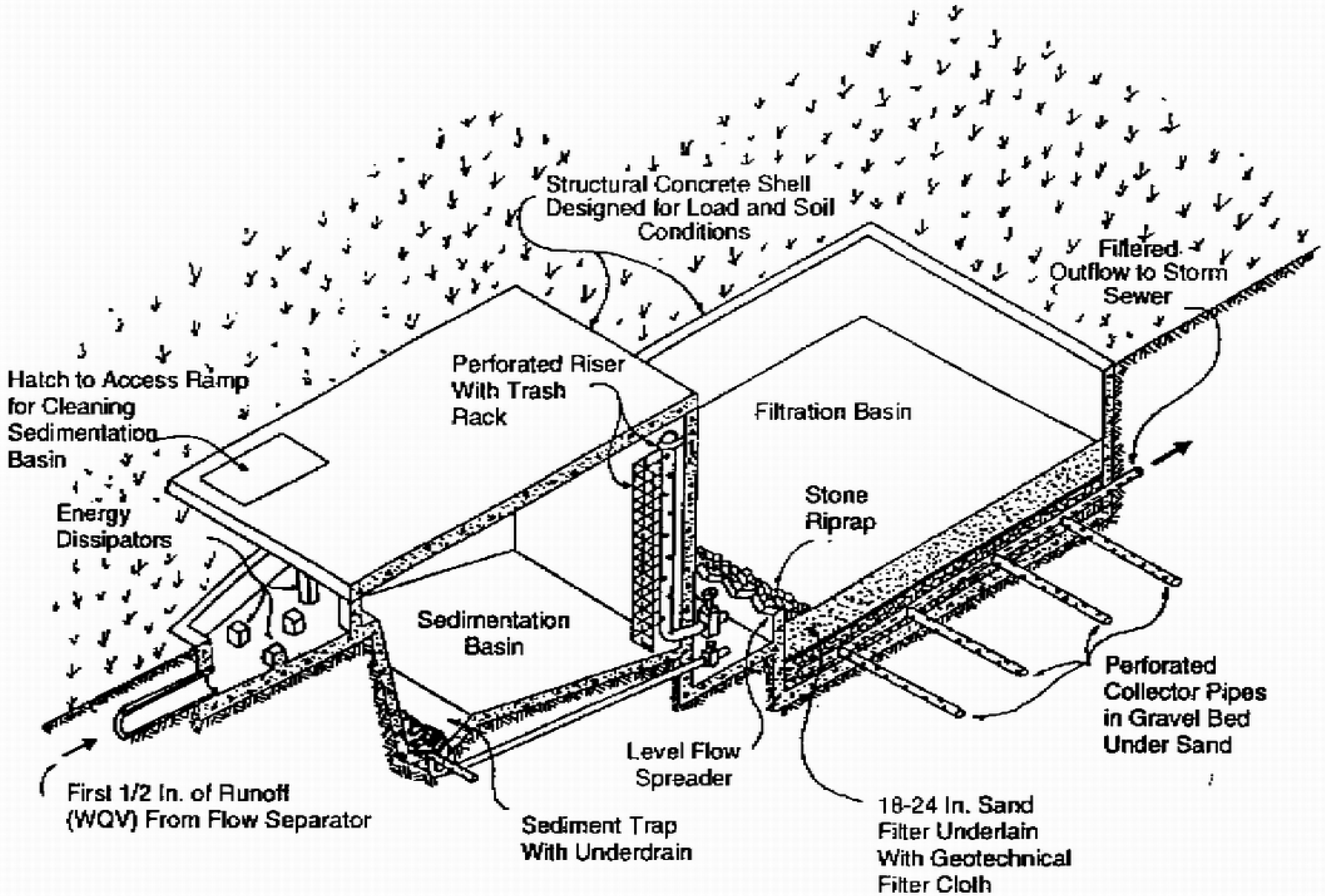
Remove accumulated paper, trash and debris every six months or as necessary

Sand Media Rehabilitation and Replacement. Over time, a layer of sediment will build up on top of the filtration media which can inhibit the percolation of runoff. Experience has shown that this sediment can be readily scraped off during dry periods with steel rakes or other devices. Once sediment is removed the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Eventually, however, finer sediments which have penetrated deeper into the filtration media will reduce the permeability to unacceptable levels, thus necessitating replacement of some or all of the sand. The frequency in which the sand media must be replaced is not well established and will depend on the suspended solids levels entering the system. Drainage areas which have disturbed areas containing clay soils will likely necessitate more frequent replacement. Properly designed and maintained sand filtration BMPs in arid climates, have functioned effectively, without complete replacement of the sand media, for at least five years and should have design lives of 10 to 20 years.


Inflow
Diversion weir
A
A
To Facility
PLAN VIEW
Overflow/Bypass


Diversion weir
To Facility
SECTION A-A
Inflow beyond diversion weir.


SLOTS/WEIR
GRATED COVER
WATER LEVEL
SOLID COVER
Weir Flow
OVERLAND FLOW
SEDIMENTATION CHAMBER (HEAVY SEDIMENT, ORGANIC DEBRIS)
18" DEEP FINE SAND
OUTFALL PIPE- SCREEN OPENING AT SAND FILTER WITH FILTER FABRIC OVER DURABLE SCREEN MATERIAL.
CONCRETE (May need reinforcement if placed in traffic areas)


Structural Concrete Shell
Designed for Load and Soil
Conditions
Filtered
Outflow to Storm
Sewer
Hatch to Access Ramp
for Cleaning
Sedimentation
Basin
Perforated Riser
With Trash
Rack
Filtration Basin
Energy
Dissipators
Stone
Riprap
Sedimentation
Basin
Perforated
Collector Pipes
in Gravel Bed
Under Sand
Level Flow
Spreader
First 1/2 In. of Runoff
(WQV) From Flow Separator
Sediment Trap
With Underdrain
18-24 In. Sand
Filter Underlain
With Geotechnical
Filter Cloth